

XEROMYS MYOIDES THOMAS, 1889 (RODENTIA: MURIDAE) IN MANGROVE COMMUNITIES OF NORTH STRADBROKE ISLAND, SOUTHEAST QUEENSLAND

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Seven mangrove communities spanning the north-south length of western North Stradbroke Island were surveyed between 1991 and 1993 for *Xeromys myoides*. It was recorded at all sites, a total of 111 individuals was captured and home range estimates and ecological data were recorded for nine individuals. The life history of this small, spotted, specialised, non-aquatic, non-arboreal, nocturnal rodent revolved around the island's mangrove and adjacent sedgeland communities. It nested in either large termitarium-like mounds or simple tunnels in the supralittoral bank. Nests contained up to eight individuals of all age groups and either sex, with one adult male present in the resident group. From their nests, rats followed the receding tide out through sedgeland and into the mangroves where they foraged over a home range estimated at approximately 0.8ha for males and 0.6ha for females. Home ranges overlapped slightly, but core areas, estimated at around 0.2ha, did not. Home range size was thought to be determined by the complexity of the mangrove community as reflected in the structural diversity of the mangrove substrate. The diet of *X. myoides* consisted of small crustaceans (mainly the crabs *Parasesarma erythrodactyla* and *Helice leachi*), marine polychaetes, marine pulmonates and marine bivalves. The species was recorded in breeding condition throughout most of the year. It is proposed that the unusual life-style of this rodent might be linked to problems associated with the need to dissipate heat rather than the necessity to retain it. Caution should be exercised in attributing its locally abundant status on North Stradbroke Island to populations on the mainland which await assessment. □ *Xeromys*, False Water-rat, rodents, mangroves, North Stradbroke Island.

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The False Water-rat *Xeromys myoides* Thomas, 1889 (Fig. 1) is a small, poorly known Australian hydromyine rodent. Fourteen museum specimens are known (Van Dyck & Durbidge, 1992). These and other specimens liberated after capture, have been collected from mangrove forests, freshwater lagoons, swamps or sedged lakes close to foredunes in the Northern Territory (Parker, 1973; Redhead & McKean, 1975; Magnusson et al., 1976), coastal central Queensland (Thomas, 1889; McDougall, 1944) and coastal southeast Queensland (Dwyer et al., 1979; Van Dyck et al., 1979). It is not known whether the paucity of this record reflects genuine rarity or the inadequacy of searching effort in the appropriate habitat, however the animal is currently classified under the Commonwealth Endangered Species Protection Act 1992 as 'vulnerable'.

Xeromys myoides has been known from North Stradbroke Island, Queensland since 1978 when an adult female was hand-caught by students at Myora Springs (Van Dyck et al., 1979). This specimen represented the most southerly record for the species. In 1992, Ellie Durbidge and I recorded the capture of another adult female

trapped near one of a number of reed-covered peat mounds in sedgelands of the Myora wetlands (Van Dyck, 1992, 1994; Van Dyck & Durbidge, 1992). These reports commented on the similarity of the large, termitarium-like nesting mounds to that described by Magnusson et al. (1976) from Melville Island but, in addition, noted the presence of relatively simple tunnels built into the supralittoral bank at the marine-sedgeland/freshwater-wallum (*Banksia* tree-heath on humus podzols) ecotone. In tentatively attributing these simple tunnels to *X. myoides* the possibility was raised that the absence of large nesting mounds in appropriate habitat may not be a reliable gross indicator of the absence of *X. myoides*.

In an attempt to clarify the distribution of *X. myoides* in the mangrove communities of North Stradbroke Island, nest recording and trapping surveys were conducted from near Amity on the island's north-westerly tip, to Jumpinpin, the island's southern extremity 36km south (Figs 2-6). Radiotelemetry of animals trapped and released was expected to generate some preliminary information for the species on diet,



FIG. 1. *Xeromys myoides*, adult female from Rainbow Channel, North Stradbroke Island (Bruce Cowell).

home range, foraging behaviour and aquatic adaptation.

METHODS

FIELD SURVEYS. Field observations and surveys associated with this study were made between 3 Nov 1991 and 18 Nov 1993. Fieldwork prior to Sept 1992 concentrated on nest appraisal, capture and radiotelemetry of individuals at and near the Rainbow Channel (site 2, Fig. 3), while the latter part documented the presence of *X. myoides* in six other areas of mangrove habitat along the western side of the island (Figs 2-6).

CAPTURE TECHNIQUES. Elliott (Elliott Scientific, Upwey, Victoria) size A aluminium traps (300x100x90mm) were used. Up until Sept 1992 trapping was conducted only at or near nesting mounds, none of which was found constructed inside the mangrove zone but in sedges of the supralittoral zone. Thereafter, given the initial results of direct observation through radiotelemetry, traps were laid along the floor of the mangrove forest. A white cotton string-line guide was laid simultaneously. Traps, baited with

chunks of chopped mullet or gar, were placed among mangrove roots, beside trunks with base hollows, among pneumatophores or inside hollow logs. Traps were not set up in trees.

Normal terrestrial trapping protocol was adjusted to accommodate threats of drowning implicit in the method. Live-trapping on the mangrove floor required local knowledge of both the upper inundation height of night high tides and the rates of incoming tides as traps required checking and tripping prior to their inundation. A rising tide combined with too many traps set over a long mangrove transect (e.g., 75 traps over 1km) proved a drowning hazard to trapped rats and a formidable task for one person in a night. Looping of mangrove traplines (25 traps per loop) north and south of a 'central' land-based camp gave adequate coverage of mangrove forest, and quicker access to both traps and the station associated with processing captures. Trapping was carried out during the following periods: Nov 1991 (8 trap nights); Feb 1992 (13 trap nights); May 1992 (249 trap nights); June 1992 (29 trap nights); July 1992 (196 trap nights); August 1992 (188 trap nights); September 1992 (263 trap nights); October 1992 (50 trap nights); November



FIG. 2. Sites (1-7) surveyed for *Xeromys myoides* on North Stradbroke Island.

1992 (50 trap nights); December 1992 (100 trap nights); Jan 1993 (50 trap nights); March 1993 (70 trap nights); May 1993 (50 trap nights); July 1993 (40 trap nights); October 1993 (40 trap nights); November 1993 (36 trap nights). Trap nights totalled 1480 and covered sites at Chiggil Chiggil, Rainbow Channel, Myora Springs, Two Mile, Deanbilla, Canalpin Ck and Stockyard (see Table 1, Figs 2-6).

In open *Avicennia marina* woodland such as at Canalpin Creek, where old trees were widely spaced and the substrate simple, it was possible to spotlight for *X. myoides* among pneumatophores and capture them by hand.

No attempt was made to dig individuals from nests and no nesting mounds were breached.

HANDLING AND RADIO-TRACKING PROCEDURES. Captured individuals were weighed, measured, sexed, and assessed for reproductive

condition and individual traits (tail kinks, albinism in tail-tip, ear damage etc.). Initial difficulty in determining sex in juveniles and sub-adults was resolved using a measure of the distance between the anus and the urogenital opening ('anal-genital distance') which was significantly less in females (Table 2). *X. myoides* rarely struggled, and gave the impression of being almost incapacitated by fear. However, when handled with ungloved hands they inflicted deep bites, so were restrained for measuring through a cloth collecting bag rolled back to give access to the animals. Dorsal spotting patterns were recorded (Table 2), and each animal was assigned to an age category by weight: J (juvenile) <28g; SA (sub-adult) 28-35g; A (adult) >35g. Each animal was individually tagged. Initially, animals were tagged on one ear with a numbered brass tag (Hauptner-Ohrmarken #73850) or a 'fish & small mammal tag' (No. 1005-1, size 1, National Band and Tag Co, Newport, KY). Both tag types proved unsatisfactory and were found to have been ripped from ears after a

few days. Finally, a system of ear nicks was used. A simple 2mm cut was made in the edge of the pinna with small surgical scissors dipped in tattoo ink. Using well-defined areas of the upper and lower folds of the pinnae, a wide range of identificatory combinations was available. Ear cuts healed and rejoined quickly, leaving a fine black line readily discernable when torch-illuminated from behind the pinna.

Trapped animals were measured (Table 2) and released before dawn at their point of capture, or their nest (where known). In cases where a nest site was not known for an individual and the incoming tide had covered the capture site, the animal was deposited nearest the trap site in a low mangrove hollow that provided cover and easy access to the ground. Animals responded passively but poorly to being held over for measurement during the day following their capture, and

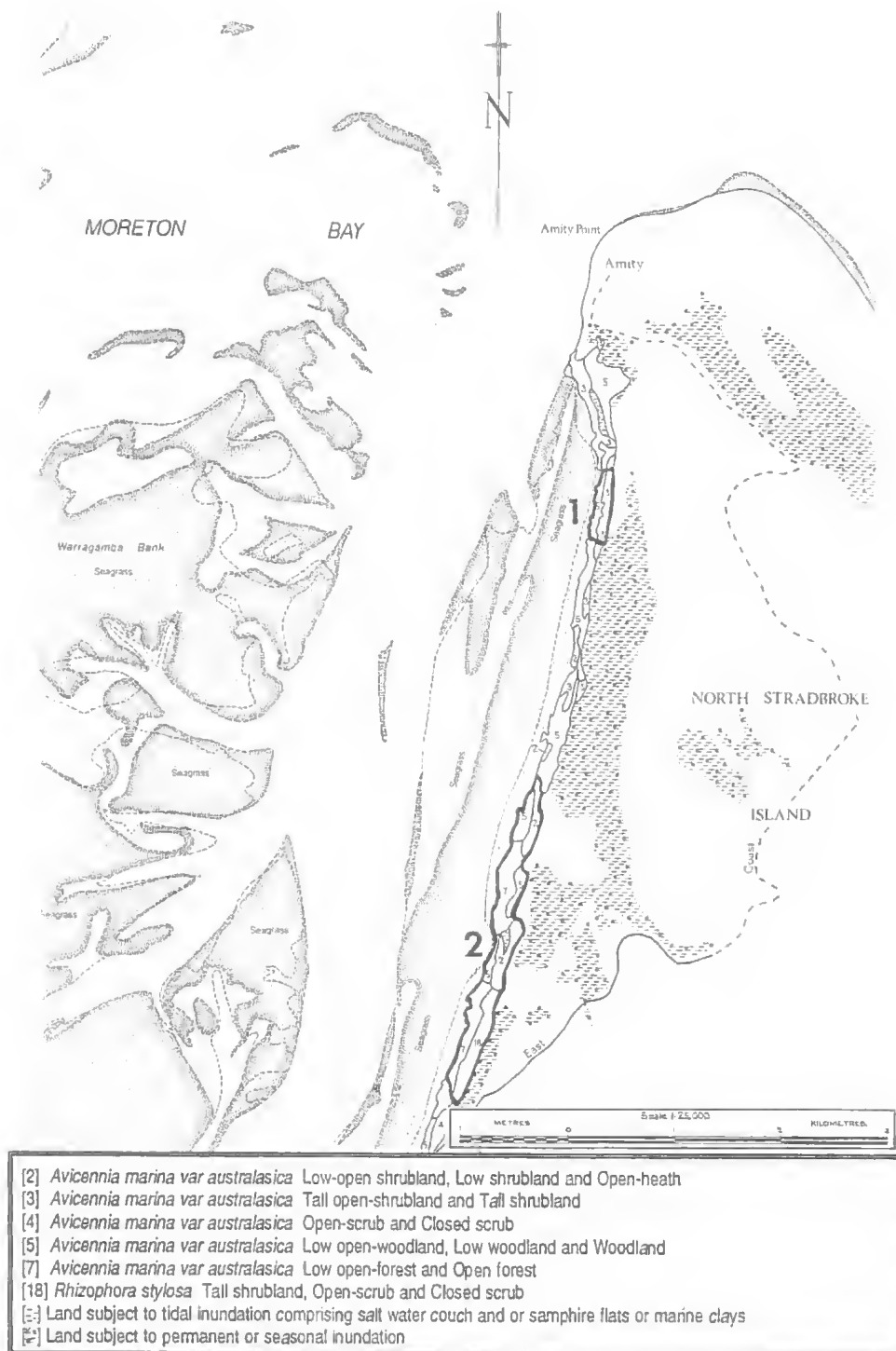
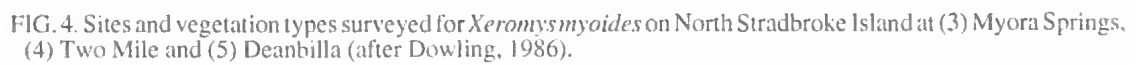


FIG. 3. Sites and vegetation types surveyed for *Xeromys myoides* on North Stradbroke Island at (1) Chiggil Chiggil and (2) Rainbow Channel (after Dowling, 1986).



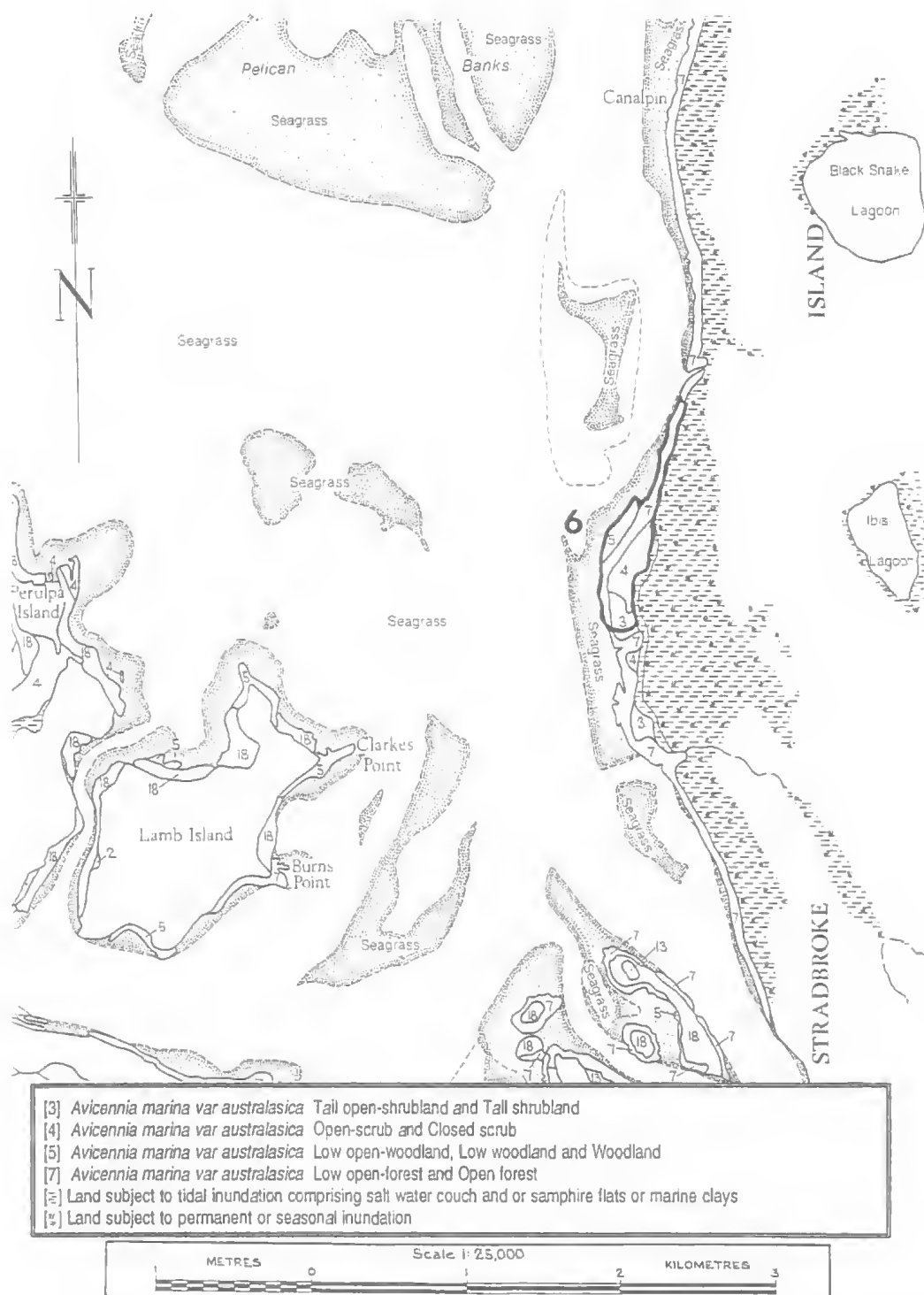


FIG. 5. Sites and vegetation types surveyed for *Xeromys myoides* on North Stradbroke Island at (6) Canalpin Ck (after Dowling, 1986).

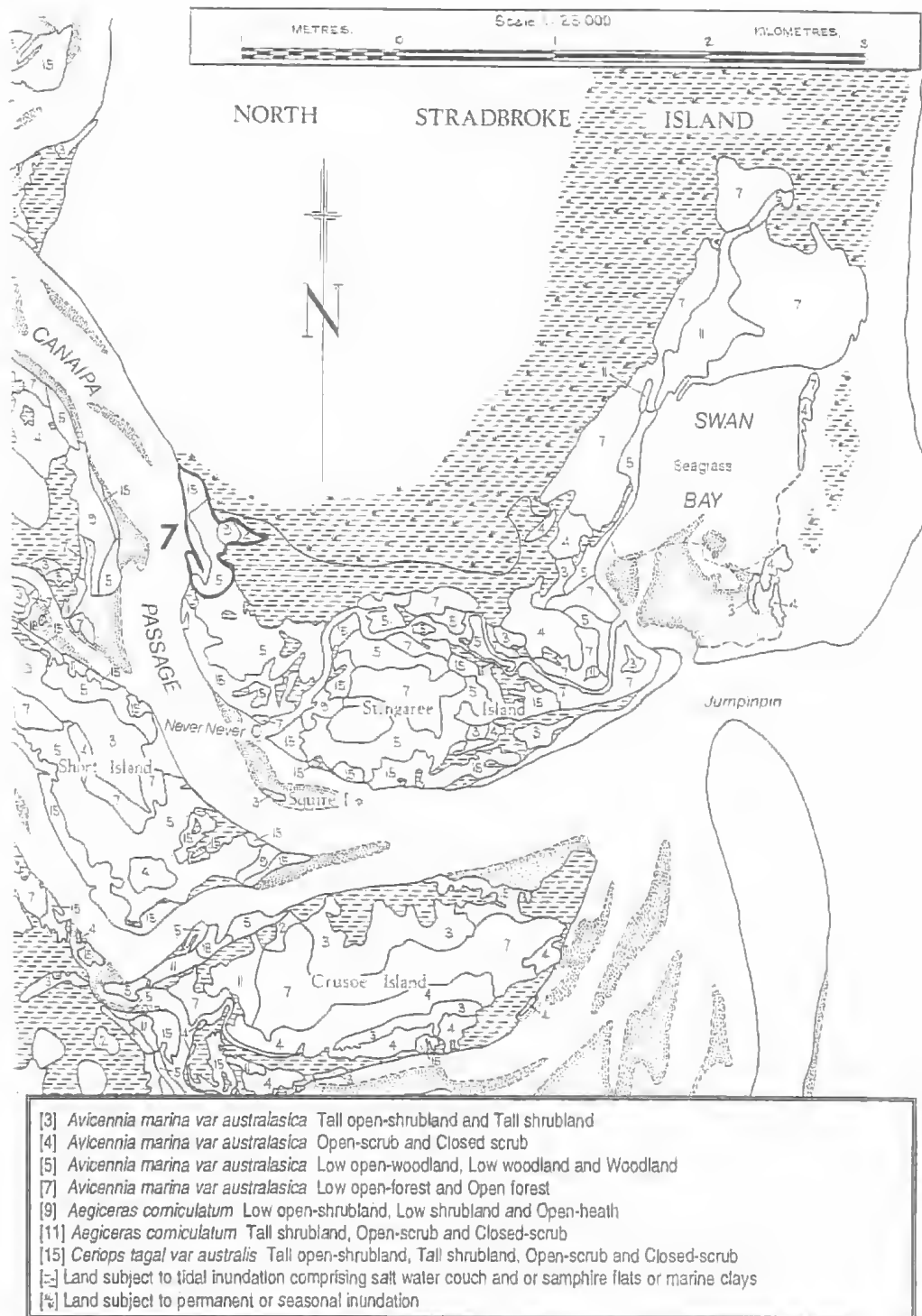


FIG. 6. Sites and vegetation types surveyed for *Xeromys myoides* on North Stradbroke Island at (7) Stockyard (after Dowling, 1986).

TABLE 1. North Stradbroke Island sites surveyed, vegetation types and trapping results for *Xeromys myoides*.

Site	Latitude/Longitude block	Vegetation type(s)	Trap Nights	Captures	Recaptures	Individuals
1 Chiggil Chiggil	27°25'00-10"S 153°26'13-19"E	3,5	64	8	1	7
2 Rainbow Channel	27°27'06"-28°00"S 153°25'22-49"E	2,3,5,7,18	1153	128	48	80
3 Myora Springs	27°28'10-21"S 153°25'18-26"E	4,5	25	6	0	6
4 Two Mile	27°28'43-53"S 153°24'31-49"E	7	25	1	0	1
5 Deanbilla	27°30'48"-31°09"S 153°24'41-47"E	5	45	8	1	7
6 Canalpin Ck	27°36'08-44"S 153°24'22-42"E	3,4,5,7	70	6	0	6
7 Stockyard	27°43'28-46"S 153°24'17-30"E	4,5,9,15	50	5	1	4
Totals			1432	162	51	111

in some cases behaved in an ataxic manner when released the following evening. Rats used in radio tracking were fitted with a Titley (Ballina, NSW) 'Microlite', two-stage transmitter either attached to a cable-tie collar with a protruding 15cm whip antenna or epoxy-potted into a small rectangular tablet (length 17.7mm, breadth 9.3mm, height 6.8mm) with a protruding 18.5cm antenna. The ventral surface of the epoxy disc transmitter was glued to a 20mm x 10mm piece of cloth which was in turn glued to the animal's rump (Selley's Supa Glue) after a square of fur approximating the dimensions of the cloth had first been cropped close to the rat's skin. The short hair that remained provided a bonding surface for the glue on the transmitter cloth and long hair surrounding the positioned disc was then glued over the dorsal surface of the cloth and transmitter. Given the small size of the animal and the saline nature of its environment, battery size (hence longevity and range) had to be traded against weight of the waterproofing agent protecting the unit. Total weights of transmitter packages were approximately 1.8g (collar) and 1.3g (glue-on). As recapture of individual rats was unreliable, collars were abandoned early in the study in favour of glue-on units that could be removed more easily by the rodents. A drawback associated with glue-on units was the ability of rats to twist around and bite the transmitter package. Any intrusion of saltwater into the unit resulted in electrolysis that rendered it inoperable. Glue-on units usually only lasted on an individual for two nights. A 2000 channel 'Regal 2000' (Titley) portable receiver operating on the 150.000-151.999mHz band, and a 2 element hand-held H-frame antenna were used to locate animals.

HOME RANGE DETERMINATION. Home range estimates were determined between May 1992 and March 1993 for four adult females, four adult males and one sub-adult male (Table 3). Because visits to the area were irregular and

transmitter life was often unpredictable, animals were tracked soon after capture and thereafter for one or two nights. Length of tracking period was always dependent on the time of capture measured against height and time of the night high tide. As animals usually stayed in their nest until the tide receded, up to four hours of telemetry might be lost in a night to a high tide. All *X. myoides* studied on North Stradbroke were nocturnal. Tracking was continuous and direct observation was used to maximise return of ecological information. Places visited on a rat's traversed route were marked with flagging tape complete with time of recording and subsequently surveyed during the day.

The pattern of habitat use by *X. myoides* was not uniform throughout its entire home range and a percentage usage pattern defined by the 95th and 65th percent probability isopleth proved a most desirable method for estimating home ranges and core areas. Swihart & Slade (1985) have commented that direct observation through continuous tracking may lead to an underestimation of home range size through loss of independence of fixes. To test this, ten-minute fixes were extracted from examination of each of the nine routes plotted through time. Home range estimates arrived at through this method greatly underestimated observed patterns of usage and failed to demonstrate a picture of overlap. Fixes taken for each animal followed are outlined in Table 3. Estimates of home range area were generated using the harmonic mean distance minimum (HM, see Dixon & Chapman, 1980) and the minimum convex polygon (MCP: Mohr, 1974). The utility and appropriateness of the HM for describing home ranges of small, fast-moving mammals was demonstrated by Quin et al. (1992). Estimates were generated with the RANGES 4m computer package.

SPOTLIGHTING, DIET ASSESSMENT AND NEST ENDOSCOPY. Radio-tagged animals

	N	Mean	OR	SD	CV
Head-Body Length					
adult (>35g)	42M	102.4	86.4-123.3	8.32	8.12
	26F	98.3	83.1-119.8	8.84	8.99
sub-adult (28-35g)	7M	91.6	83.4-99.0	5.17	5.64
	23F	88.6	76.0-103.5	6.03	6.80
juvenile (<28g)	5M	81.8	70.2-94.1	7.75	9.56
	7F	81.9	62.3-94.8	10.27	12.54
Tail-Vent Length					
adult	43M	81.8	69.3-90.0	5.32	6.50
	26F	80.0	74.4-87.5	3.90	4.87
sub-adult	7M	76.0	67.8-91.0	7.56	9.94
	23F	73.8	67.7-84.2	4.16	5.64
juvenile	5M	63.8	59.0-70.8	4.48	7.02
	7F	67.7	59.7-74.1	4.30	6.35
Hind Foot Length (su)					
adult	43M	23.2	21.6-24.6	0.79	3.23
	26F	22.1	21.0-24.1	0.70	3.17
sub-adult	7M	22.9	22.0-24.0	0.68	2.97
	23F	21.7	20.9-22.8	0.54	2.49
juvenile	5M	20.6	19.9-22.0	0.78	3.79
	7F	21.0	19.7-21.7	0.74	3.52
Ear (from notch)					
adult	42M	12.5	10.5-14.0	0.72	5.76
	25F	12.5	10.7-14.4	0.70	6.32
sub-adult	7M	11.8	11.2-12.3	0.37	3.13
	23F	12.1	10.1-13.8	0.87	7.19
juvenile	5M	11.7	10.4-13.1	1.02	8.72
	6F	11.8	10.0-12.8	0.96	8.13
Anal-Genital Distance					
adult	42M	17.3	10.8-23.2	3.34	19.31
	23F	7.0	4.1-9.7	1.45	20.71
sub-adult	7M	14.1	12.5-17.3	1.52	10.78
	22F	5.8	3.5-7.0	0.79	13.62
juvenile	5M	11.2	8.0-16.2	2.79	24.91
	7F	6.1	5.4-6.4	0.37	6.06
Weight (g)					
adult	42M	46.6	36.0-59.0	6.04	12.96
	26F	42.0	36.0-54.0	5.06	12.04
sub-adult	7M	32.0	28.0-35.0	2.39	7.46
	23F	31.5	28.0-35.0	2.20	6.98
juvenile	5M	31.8	18.0-26.0	3.12	14.31
	7F	24.1	18.0-27.0	3.36	13.94
Spotting					
	N	With	Without		
adult	43M	40	3		
	26F	25	1		
sub-adult	7M	5	2		
	23F	15	1		
juvenile	5M	0	5		
	7F	4	3		

TABLE 2. Measurements, and incidence of dorsal spotting for *Xeromys myoides* from North Stradbroke Is. N=number, OR=observed range, SD=standard deviation, CV=coefficient of variation. Lengths in mm.

were observed with 'Mag-Lite' (Mag Instruments, Ontario, Calif) torches. The expanding beam of these torches greatly facilitated detection of rats moving among mangrove roots. A total of 57 hours was spent observing wild *X. myoides* (Table 3). Rats were more difficult to locate inside densely vegetated communities (e.g., Rainbow Channel), but in areas of low vegetation complexity (e.g., Canalpin Creek, Chiggil Chiggil) the white bellies of running rats were conspicuous. Animals were generally silent and in torchlight the eyes reflected poorly (dull mauve). The diet was assessed by directly observing (with binoculars) radio-tagged rats while they fed, and by the analysis of middens attributed to the rats. Rats were interrupted soon after they began to eat soft prey and the food remnants were pirated for identification. Crustacean prey were identified from skeletal fragments collected after the meal. Faecal pellets were sampled from many animals, but apart from parasites, their contents consisted mostly of minute fragments of unidentifiable crustacean shell and integument.

Non-intrusive observation inside nesting-mound tunnels, nest chambers and of nestling young was facilitated by the use of an endoscope (Olympus GIF type P2) and cold light supply (Olympus CLE-3) powered by a portable Honda 240V generator. Extensive convolution of tunnels in nest mounds made it impossible to reach nest chambers if the endoscope was inserted through a natural entrance. However, it was possible to reach nest chambers using a 15mm-wide hollow coring rod (fibreglass fishing rod) pushed and twisted gently into the roof of the mound. When a lack of resistance in the passage of the rod was detected, the coring rod was extracted, cleaned out, reinserted, and the flexible endoscope tube then introduced and an examination of the area made.

STUDY SITE AND HABITAT. At each site surveyed for *X. myoides*, all mangrove species were noted and the vegetation was classified visually according to density and height into one of the community types of Dowling (1986) described below.

North Stradbroke Island, which forms the major part of the eastern boundary of Moreton Bay, lies 40km east of Brisbane. The island is triangular in shape, 36km long from north to

south and about 285 km² in area (Fig. 2). Physiography, geology, soils, climate, hydrology and plant communities of this humid subtropical island are broadly outlined in Stevens & Monroe (1975), Clifford & Specht (1979), Covacevich & Durbidge (1981) and Coleman et al. (1984). North Stradbroke Island's western mangrove communities facing the shelter of Moreton Bay are characterised by three ubiquitous and dominant plant species (*Avicennia marina*, *Rhizophora stylosa* and *Bruguiera gymnorhiza*) of wide ecological amplitude, i.e., tolerant of a wide range of salinity and temperature regimes (Bunt et al., 1982). The drainage basin supporting the mangrove communities is in a relatively low-rainfall range (Dunwich annual precipitation 1602 mm) but with an intermediate to low run-off coefficient (ratio of run-off to rainfall, 0.2-0.5) which, given the island's extensive swamps, overflow basins, dense vegetation and sandy substrate, allows considerable retention of water with more regulated and sustained release to the drainage systems (Hutchings & Saenger, 1987). However, in backing onto *Melaleuca quinquenervia* swamps and other poorly drained areas, as commonly is the case, the full development of many mangroves zones is impeded in comparison to those zones abutting better drained and drier areas (Dowling, 1979).

The mangrove communities most commonly associated with this study (Table 1) comprised *Avicennia marina* var. *australasica*, *Rhizophora stylosa* and *Bruguiera gymnorhiza*. Two other species, *Aegiceras corniculatum* and *Ceriops tagal* var. *australis* were more commonly represented toward the southern end of the island. Species descriptions and community compositions for this group in Moreton Bay can be found in Dowling (1986), from which only broad characteristics relevant to this study are summarised below.

Avicennia marina var. *australasica*, the most common and widespread species found in Moreton Bay, occurs in any part of the intertidal zone, either as a pure stand or mixed with other species, but usually as an emergent. It is also the most variable species in Moreton Bay, being represented as large, well-developed trees from 10-12 m (or more) tall, or as small spreading shrubs only 0.5 m tall when fully developed. Its growth is tallest and most vigorous when this species stands at the extreme seaward edge in well-drained soils that are inundated by all high tides. At the upper tidal limits its growth is less vigorous and it usually occurs as a small shrub. In areas of

poor drainage, but frequent tidal inundation, *A. marina* forms a low spindly tree. Where freshwater seepage occurs this species tends to form stunted, round, leafy bushes. Death of *Avicennia marina* occurs with waterlogging, ponding of water and siltation leading to the covering of pneumatophores. The structural forms of *Avicennia marina* encountered during this study ranged from Low open-shrubland, Low shrubland and Open-heath (mapping unit 2), Tall open-shrubland and Tall shrubland (mapping unit 3), Low open-woodland, Low woodland and Woodland (mapping unit 5) and Low open-forest and Open-forest (mapping unit 7) (Fig. 7; see Dowling, 1979, 1986 for definitions and descriptions).

Throughout Moreton Bay, *Rhizophora stylosa* occurs either as solitary trees, in clumps of three to five, or in pure stands of densely-packed trees. It may also occur in association with other mangrove species as a large, single-stemmed shrub or small tree toward the lower tidal limits or occasionally in a very narrow zone behind the seaward fringe of *A. marina*. Freshwater from *Melaleuca* swamps is thought to stunt the development of this species (Dowling, 1986). In the study area *R. stylosa* grew in both isolated clumps and in thick belts. Trees growing in clumps were represented by individuals of different heights (1-4 m) and age. Belts of this species were found behind the seaward fringe of *Avicennia marina* and extended to the landward edge. Here the trunks were more erect and unbranched, the prop and stilt roots tangled to 1 m above the ground and the branches did not spread laterally. Structural forms of *R. stylosa* encountered during this study consisted of Tall shrubland, Open-scrub and Closed-scrub (Fig. 8; mapping unit 18; Dowling, 1986).

Bruguiera gymnorhiza occurs in Moreton Bay as scattered plants or small clumps of 10-15 trees on the most landward fringes. It is found on hard consolidated muds or peaty clays and is most common in areas of freshwater seepage from the supralittoral zone. In the study area it did not occur in communities, but as solitary trees up to 4 m or small clumps (two to five trees).

Aegiceras corniculatum (2 m tall) occurred adjacent to the reed zone on the landward side of the Canalpin Creek and Stockyard sites. This species grows on firm muds which have a shallow layer of soft mud on top. It grows on poorly-drained soils that are shallowly inundated by most high tides. Structural forms encountered included Low open-shrubland and Open-heath (mapping unit 9).



FIG. 7. *Avicennia marina* low open-woodland, Rainbow Channel (Bruce Cowell).



FIG. 8. *Rhizophora stylosa* open-scrub, Rainbow Channel (Bruce Cowell).

Ceriops tagal var. *australis* occurred only at the upper tidal limit of the Stockyard site. Normally, *Ceriops* communities are inundated only by a few tides each month, and they occur on firm, well-drained clays, clayey muds or sandy clays. The structural forms encountered included Tall open-shrubland, Tall shrubland, Open-scrub and Closed-scrub (mapping unit 15).

The floor of the mangrove community provided an array of microhabitats including tidal pools, channels, crab holes, pneumatophores, crevices in bark and around roots, hollows in standing and fallen timber, suspended drifts of twigs and leaves, driftwood, detritus and tide-washed garbage. The complexity of microhabitats varied according to the structure of the mangrove community. Highest structural floor diversity occurred in the species-rich communities at Rainbow Channel (Fig. 8) followed by those at Stockyard. Lowest structural floor diversity occurred in the *Avicennia* woodlands of Canalpin Ck and Chiggil Chiggil.

On the landward side, mangroves were abutted by either a discrete zone of sedgeland, *Melaleuca quinquenervia* swamp/*Eucalyptus robusta* forest alliance, or heathland (Fig. 9). The sedgeland band (1.2m high) in which salinity is reduced by drainage from the mainland, comprised almost exclusively *Juncus kraussii*, *Baumea juncea*, *B. rubiginosa* and *Finbristilis ferruginea*. In many places this zone was up to 30m wide and was sharply delineated from both the upper reaches of the mangrove woodland tract and the lowest extent of the wallum (dominated by *Melaleuca quinquenervia*, *Eucalyptus intermedia*, *E. robusta*, *Leptospermum liversidgei*, *Gahnia sieberiana* and *Caustis blakei*).

Supralittoral banks, formed by the combined effects of spring tides, wind setup and storm



FIG. 9. Aerial view of Rainbow Channel study site showing zonation from marine meadow (bottom) through mangrove community and sedge zone to freshwater swamp/wallum woodland (top) (Bruce Cowell).

surge, occurred at the sedgeland/wallum or mangrove/freshwater marsh ecotones. The Canalpin supralittoral bank, at 95cm high, was the tallest bank encountered. In some areas (e.g., Deanbilla) it was poorly defined. In most areas where this bank abutted wallum, the groundsel *Baccharis halimifolia* was a dominant species along the bank. After periods of rain, freshwater percolated through the supralittoral banks and the integrity of the bank depended on its consolidation by the roots of salt-tolerant species such as *M. quin-*

TABLE 3. Home Range estimates, linear distances covered and allocation of time in *X. myoides*. HM 95%=95% isopleth of the Harmonic Mean Measure, MCP=Minimum Convex Polygon, Dist(m)=linear distance covered during observation time (Obs. time).

Animal	Date	#Fixes	Home Range (ha)			Dist(m)	Obs. time	%foraging	%resting
			HM 95%	Core 60-65%	MCP				
AF4	2.5.92	35	0.41	0.13-0.18	0.45	539	4hr 54min	80.3	19.7
AF21	28.1.93	25	0.46	0.10-0.16	0.30	407	1hr 36min	100	0.0
AF31	20.8.92	67	0.80	0.23-0.33	0.82	833	5hr 21min	68.2	31.8
AF69	10.12.92	59	0.70	0.22-0.32	0.54	1063	3hr 14min	92.8	7.2
AM16	27.7.92	57	0.93	0.10-0.13	0.86	895	5hr 00min	67.3	32.7
AM33	22.8.92	120	0.65	0.19-0.22	0.70	2170	9hr 32min	94.5	5.5
AM68	3.12.92	126	0.77	0.24-0.29	0.74	1227	2hr 48min	95.8	4.2
AM89	20.3.93	105	7.35	0.47-1.06	3.42	2891	9hr 11min	86.9	13.1
SAM34	11.9.92	38	0.38	0.12-0.17	0.50	514	2hr 34min	87.7	12.3

quenervia and *Casuarina glauca*. Where these species were absent (e.g., Canalpin), the supralittoral bank experienced dramatic scouring and profile changes.

RESULTS

DISTRIBUTION AND TRAPPABILITY. *Xeromys myoides* was recorded from all island mangrove communities surveyed between Chiggil Chiggil and Stockyard (see Table 1).

The species was apparently not trap-shy. A total of 111 *X. myoides* individuals were trapped and 24 individuals were retrapped (Table 5). Trapping success for new captures was higher in mangrove transects compared to 'barricade' trapping where up to eight traps were set in a ring around a nesting mound in sedgeland (total traps set in mangroves = 606, trapping success for first captures = 11.7%; total traps set around sedgeland nest = 710, success for first captures = 3.9%). Overall success (first captures and recaptures) from mangrove vs. nest settings was slightly higher in mangroves (mangrove trap success 11.4%, nest success 8.4%). The total number of sub-adult males trapped (seven) was low. If traps were left open through the day high tide, bait was usually eaten by toadfish (*Tetractenos hamiltoni*, *Marilyna pleurostricta*) or traps were upturned by Mud Crabs (*Scylla serrata*).

Capture of taxa other than *X. myoides* was rare. Five *Melomys burtoni* were caught (Capembah Creek, 1 & 4 May 1992 at the mangrove/dry woodland ecotone, two individuals; and Deanbilla, 25 September 1992 in mangroves; three individuals); *M. cervinipes* was trapped at Deanbilla, 26 November 1992 in mangroves (1 individual); and two *Rattus lutreolus* were caught

at nest-site G of *X. myoides* at Rainbow Channel, 1 May 1992 and 22 August 1992 at the sedgeland/dry woodland ecotone. Cane Toads (*Bufo marinus*) were frequently seen or caught in sedgeland traps in the Rainbow Channel site and in mangroves of the Canalpin Creek site. One Lewin's Rail *Rallus pectoralis* was trapped overnight in sedges at nest-site B, Rainbow Channel. Surprisingly, no *Hydromys chrysogaster* were seen or trapped during the study, although the dismembered remains of a large Mud Crab (*Scylla serrata*) were noted at Myora Springs. The presence of the Water Rat was suspected at the Rainbow Channel site where numerous traps were found tripped, their baits removed and eaten close by.

During the study only one *Rattus rattus* was observed (running along the prop roots of *R. stylosa* trees), but numerous middens and food caches attributed to that species were recorded in trees. Measurements of *Xeromys myoides* from North Stradbroke Island appear in Table 2.

NESTING. *Xeromys myoides* nested in a wide variety of sites, and nest forms varied considerably, ranging from large termitarium-like mounds up to 60cm high built in the marine sedgeland (Fig. 10) to inconspicuous tunnels excavated in the supralittoral bank at the marine-sedgeland/freshwater-wallum ecotone. Six large mounds were recorded from within the Rainbow Channel site and one from Stockyard. Adjacent nest mounds were separated by distances of between 80 and 410m. Mounds were constructed of a mixture of excavated peat, sedge straw, mud and sand. They were from 20cm to 60cm high with basal circumferences from 1.6m to 4.8m. From one to three entrance holes were found at each

TABLE 4. Residency in nest mounds presumed to be used by more than one animal. Individuals trapped at nest. * Individuals re-trapped in mangroves directly in front of nest. # Transmitter day-fix.

Nest	Animal No.	Age	Sex	Capture Date	Recapture Date(s)
H	8	A	M	26.2.92	-
	27	A	M	6.8.92	21.8.92*
	26	♂	F	6.8.92	-
	28	SA	F	6.8.92	-
	8	SA	F	18.6.92	-
	13	♂	M	3.5.92	-
A	16#	A	M	16.7.92	18,19,27,28.7; 10.12.92*
	3	A	F	1.5.92	2.5;17.6.92
	34#	SA	M	21.8.92	22.8;10.9.92
	7	SA	M	17.6.92	18.7.92
	17	SA	F	17.7.92	27.1.93*
	12	SA	F	2.5.92	3.5;16.7;17.6.92
	25	SA	F	28.7.92	-
B	M	♂	F	2.5.92	3.5;17.6.92
	2	A	F	20.11.91	-
	4#	A	F	2.5.92	17.6.92
	18	SA	M	17.7.92	-
	19	SA	F	17.7.92	27.7;22.8.92
D	24	A	M	27.7.92	-
	20	A	F	17.7.92	18.7;19.7.92

mound, but others may have been hidden under the labyrinth of exposed tree roots into which mounds were often incorporated. The number of entrance holes at any one nest varied throughout the year, with disused holes quickly filling in. Regularly used holes were oval in shape (approximately 60mm by 40mm) and positioned anywhere from the top to the bottom of mounds; holes were from 30cm to 2m apart. Although lower holes were flooded at high tide, the mounds themselves were never seen to have been entirely inundated (Fig 11).

Evidence of external mound 'workings' consisted of fresh roof 'plasterings' in which a thin black paste of mud mixed with peat, dried leaves, sedge stems, or crab shells had been daubed over the top of the mound and worked between sedges (usually *Juncus kraussii*). Areas 'plastered' in this way measured as much as 0.12m² and in many cases a semi-tubular path of fresh plastering covered a track from the nest entrance hole up or around to the nest top. The absence of fresh plastering did not indicate that the nest was unoccupied, as plastering was an infrequent event. Nest-site G was first noticed on 15 Nov 1991 as

TABLE 5. Recaptures of *Xeromys myoides* (by sex, age and individual number) at Rainbow Channel.

Age	Indiv. No.	Date	Weight (g)	Age	Indiv. No.	Date	Weight (g)
Female				SA	19	17.7.92	28
A	3	1.5.92	43			27.7.92	28
		2.5.92	43	22.8.92	28		
		18.6.92	46	J	11	2.5.92	27
A	4	2.5.92	54			17.6.92	28
		18.6.92	41			Male	
A	20	17.7.92	36	A	16	16.7.92	43
		17.7.92	36			17.7.92	43
		18.7.92	36			18.7.92	43
		18.7.92	46			19.7.92	44
A	21	17.7.92	40			27.7.92	44
		17.7.92	40			28.7.92	44
		21.8.92	40			A	27
A	26	6.8.92	37	21.8.92	41		
		6.8.92	37	4	33	20.8.92	48
A	31	20.8.92	39			22.8.92	48
		22.8.92	39	J	36	21.8.92	43
A	58	19.9.92	40			22.8.92	43
		20.9.92	40	A	38	21.8.92	41
A	59	21.9.92	47			21.8.92	41
		21.10.92	42	A	82	27.11.92	50
A	66	22.8.92	37			28.11.92	50
		22.8.92	37	4	93	24.5.93	53
SA	12	2.5.92	33				
		17.6.92	32	SA	7	17.6.92	33
		18.7.92	32			18.7.92	28
		17.7.92	32	SA	18	17.7.92	35
		21.8.92	37			17.7.92	35
SA	17	22.8.92	37	SA	34	21.8.92	32
		17.7.92	31			22.8.92	32
		18.7.92	31			10.9.92	34
		19.7.92	31	J	9	2.5.92	26
		27.7.92	23			17.6.92	33

a reed-covered hole in the supralittoral bank accompanied by traces of plaster in the reed bases. By March 1993, plastering had built the mound up by 6cm and the entrance hole had been moved to the top.

Three mounds were built on slightly elevated islands supporting small patches of stunted *Melaleuca quinquenervia* and *Casuarina glauca*. One of these nests incorporated the stem of a living *Vitex trifolia* var. *bicolor* (Figs 10, 11).

Tunnels in the supralittoral bank (shaped and maintained by spring tides) were inconspicuous and generally only found by radio-tracking individuals trapped and released in the mangroves.



FIG. 10. Large nesting mound (B) built in the marine sedgeland at Rainbow Channel.



FIG. 11. Nesting mound (B) moated by high tide, Rainbow Channel.



FIG. 12. *Xeromys myoides* despatching a Red-fingered Crab *Parasesarma erythroactyla*, the most commonly eaten crustacean. (Bruce Cowell).

Four were recorded in the Rainbow Channel site and confirmed by radiotelemetry and two were recorded and confirmed from Canalpin Ck. The face of the bank, and hence the location of entrance holes, changed dramatically at Canalpin Ck with erosion of the bank caused by spring tides and freshwater runoff.

Several indications from radio-tagged individuals suggested that *Xeromys myoides* built, or at least used, extensive and complex burrow networks inside and above the supralittoral bank. One male (AM33) covered approximately 20m underground after returning to its nest when a high tide restricted foraging in the mangrove zone. One female was recorded using a system of burrows through *Galnia*-dominated freshwater swamp 10m behind the supralittoral bank at Canalpin Ck. The peat substrate of both these areas may facilitate a significant subterranean facet of life history as yet unsuspected in this species. Alternatively, *Xeromys* may have been using tunnels constructed by *Rattus lutreolus*, an extremely common species in these areas.

Although large termitarium-like nesting mounds are known to be occupied and maintained by groups of rats, the rodents' proclivity for unpretentious nesting in supralittoral banks suggests that some large nesting mounds may represent physical, historic evidence of the past position of the supralittoral shoreline. The rat's demonstrated ability to consolidate and add to

a mound, as well as the likelihood of a mound overgrowing with sedges and small trees, both increase the chances of a nest-site remaining when the rest of the bank erodes through spring tides and heavy wave action. The maintenance and extension of a nesting mound may represent a response by the occupants to a wet nesting chamber during high tides.

Over the course of the study, mound nests were found to contain animals of all three age categories (adult, sub-adult and juvenile) and of both sexes (Table 4). However, no more than one adult male was recorded concurrently in the same mound (other sexes and age categories were recorded). Adult males were observed visiting neighbouring nests during

the night, so a capture at a nest site did not necessarily imply occupancy. Adult females were noted to avoid entering a co-mounding female's burrow and if released into a 'wrong' tunnel would quickly turn around, exit the burrow and run across the mound to their 'own' tunnel. Endoscopic examination of one nesting mound (A) revealed extensive tunnel systems through the mound, with two nesting chambers within the top 16cm. Each nest was lined with the dried leaves of *Melaleuca quinquenervia*, which also littered areas around the mound. Mounds and bank tunnels provided humid protection not only during the day, but during night high tides when most *X. myoides* returned to their nests (presumably to avoid the water). One instance was noted of a



FIG. 13. Unnamed marine polychaete (30mm long), featuring in the diet of *Xeromys*. (Bruce Cowell).

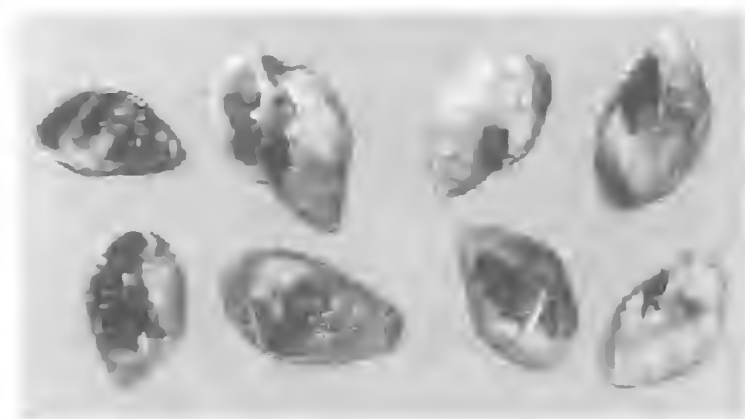


FIG. 14. Marine pulmonate *Oplicardelus quoyi* showing breaches made by *Xeromys* (Bruce Cowell).

male remaining in a hollow of a mangrove trunk during a night high tide.

DIET. The following are food items recorded by direct observation of wild *X. myoides*.

Crustacea. The small crab *Parasesarma erythrodictyla* was the most commonly recorded prey item taken inside the mangrove zone. *Xeromys myoides* ate both adults and minute juveniles (see sizes documented below). The manner of dispatching a crab was as described by Redhead & McKean (1975); crabs were first disarmed of claws, legs were bitten off, and the body turned over and breached from the softer ventral side (Fig. 12). The meat was scoured from the inside of the carapace. In some instances rats were observed to bite adult crabs between the eyes then drop and leave them, but return after a few minutes to consume the catch under suitable cover. Carapaces and basal leg segments were left uneaten, but claws were sometimes hollowed out. *Parasesarma erythrodictyla* was observed being consumed by four *X. myoides* (AF4, AF31, AM34, AM89) in the months of March, May and August.

Helice leachi (one specimen, carapace width 20mm) and *Australoplax tridentata* (one specimen, width 15mm) were recorded in the diet of AM89 at Canalpin Ck on 20 March 1993.

Marine polyclads. An undescribed marine polyclad (Fig. 13) was recorded in the diet of adult female (AF4) at Rainbow Channel, 3 May 1992. Two instances of polyclad predation were recorded on the same night. Under studio conditions, another adult female was photographed feeding on the same species. Polyclads were regularly recorded sheltering in rotting driftwood washed to the dry supralittoral zone. As many as

14 were once recorded from inside the honeycombed core of a small log (45cm long x 10cm diameter). There have been no other recorded predators of marine polyclads (L. Cannon pers. comm.).

Marine pulmonates. *Oplicardelus quoyi* (Fig. 14) was recorded being eaten by an adult female (AF4) at Rainbow Channel on 11 May 1992 (and were readily eaten by animals held in captivity). These small pulmonates gathered under driftwood in the middle of the sedgeland. Female AF4 was heard cracking *O. quoyi* under

a large plank. On examination, a midden of opened shells was found in a concavity clipped from reeds flattened under the plank. All shells had been breached through the body of the shell, and not through the aperture.

Salinator solida (Fig. 15), a small (8mm) periwinkle-like mollusc was recorded from the diet of an adult male (AM89) at Canalpin Ck on 19-20 March 1993, and was present in numbers in a Chiggil Chiggil midden. Entry to the body of the pulmonate appeared to be through the aperture as no retrieved specimens were breached.

Onchidina australis, a large (30mm), shell-less slug was eaten by an adult male (AM89) at Canalpin Ck on 20 March 1993. Parts of the gut were left uneaten.

Marine bivalves. *Glaucanome* sp. (Fig. 15), a small (11mm) sea-green mussel was eaten by an adult male (AM89) at Canalpin Ck on 20 March 1993. Opened halves of this bivalve were commonly observed across the mangrove floor, but none was recorded in *Xeromys* middens.

The following Crustacea are food items recorded from middens which were attributed to *X. myoides*:

Parasesarma erythrodictyla was the most common component of mangrove middens. One midden inside the base of a hollow *Avicennia* at Chiggil Chiggil contained 14 carapaces of this crab (average width 12mm, range 10-16mm) and four of *Helice leachi* (average width 17mm, range 15-20mm). Largest carapaces of *P. erythrodictyla* believed to have been consumed by *X. myoides* measured 20mm in width. *Helice leachi* was the most commonly recorded component of supralittoral middens. A sample of carapaces taken from a Chiggil Chiggil reed zone midden



FIG. 15. Prey taken by *Xeromys* on North Stradbroke Island, (anti-clockwise from crab) Red-fingered Crab *Parasesarma erythrodactyla*, Sea-green Mussels *Glaucanome* sp., marine pulmonates *Ophicardelus quoyi* and *Salinator solida*, unnamed marine polychaet (Bruce Cowell).

known to be used by an adult female (AF55) contained 36 carapaces (average width 17mm, range 13-21mm) and three of *Parasesarma erythrodactyla* (average width 13mm, range 11-14mm). *Peragrapsis laevis* (four specimens, average width 17mm, range 13-23mm) was recorded from a hollow *Avicennia marina* ground level spout known to be frequented by an adult female (AF31) at Rainbow Channel. Skeletal remains of the mud lobster *Laomedea healyi* were collected on 20 Aug. 1992 and 16 Sept. 1992 from a hollow *Avicennia marina* ground level spout known to be frequented by an adult female (AF31). **Diet in Captivity.** Captive specimens of *X. myoides* consumed relatively large quantities of food. During the period 20 Feb. 1995 – 4 March 1996 the average weight of raw prawns consumed daily by an adult female (of average weight during that period 38g) was 22g representing an average daily intake of 57.8% body weight (at ambient temperature 24°C). For a period of eight weeks (18 Sept. 1995 – 13 Nov. 1995) this

animal maintained body weight (average weight 38.0g, 35-40g range) on a raw prawn diet with no access to free water.

FORAGING BEHAVIOUR. Observed radio-tagged individuals of *Xeromys myoides* spent their foraging hours dashing over the substrate between trees, 'snaking' through pneumatophores and investigating hollows in mangrove trunks. Their nocturnal behaviour was generally frenetic although animals were recorded to rest inside a favoured mangrove hollow for periods of up to three hours. Linear distances covered and times spent foraging are shown in Table 3.

Generally rats left their nests and followed the receding tide out through the sedgeland and into the mangroves where they foraged. In so doing they passed through a 'common' corridor between the nest and the foraging area. In some cases this precipitated meetings (usually brief and violent) with other rats or an inspection of



FIG. 16. Typical resting hollow in an *Avicennia marina* base, Rainbow Channel (Bruce Cowell).

neighbouring nests. Animals scoured their home range during the course of an evening.

Animals visited and revisited favoured haunts such as hollows in *Avicennia* trunks, *Rhizophora* root tangles and hollow fallen logs. Large food items such as adult erabs were taken to favoured hollows (Fig. 16) where the item was consumed under cover. With time, discarded food items formed recognisable middens (Figs 17, 18). All nocturnal resting took place in such hollows. Animals climbed up inside gently sloping trunk hollows to about 1 m, but no arboreal activity was ever recorded. The favoured 'pathways' of *X. myoides* were those that ran closely alongside the low, long prop roots of *Rhizophora stylosa*, under the canopy of twigs and leaves deposited on the tops of prop roots by the fallen tide, or alongside fallen logs. In open areas of *Avicennia* forest animals ran quickly between trunks and logs in order to regain cover.

HOME RANGE DETERMINATION. Home range estimates were made for eight animals (four adult females, three adult males, one sub-adult male) from the Rainbow Channel area and 1 adult male from Canalpin Creek. Results of home range analysis and plots of nests appear in

Figures 19, 20, 21 and Table 3. There was a high degree of correlation between HM and MCP estimates. The 95% isopleth of the harmonic mean distance minimum (HM) gave an average home range area of 0.637ha for the seven adults radio-tracked at Rainbow Channel. The minimum convex polygon (MCP) average for the same seven animals was 0.614ha. The results suggested a greater home range area for males than females (male HM average 0.78 ha, MCP 0.77ha vs female HM average 0.59ha, MCP 0.53ha), but this may have been influenced by the smaller number of fixes available for females. These results should be taken as preliminary and minimal as some plots indicate that the curves had not quite asymptoted (see Quin, et al., 1992; Goldingay, 1992). The home range of the Rainbow Channel sub-adult male (SAM34) was smaller than all other males and less than the female average. The adult male (AM89) from Canalpin Creek had a home range estimated at between 7.35ha (HM 95%) and 3.42ha (MCP). Given the physiographic barriers associated with the Canalpin Creek site (salt water, dry forest and a very narrow band of mangroves, Fig. 21), the MCP estimate represents the most acceptable estimate of home range size. Core areas (averaged from the



FIG. 17. Favoured feeding hollow, in an *Avicennia marina* base, Chiggil Chiggil.



FIG. 18. *Xeromys myoides* midden from Rainbow Channel showing mainly crab shell fragments.

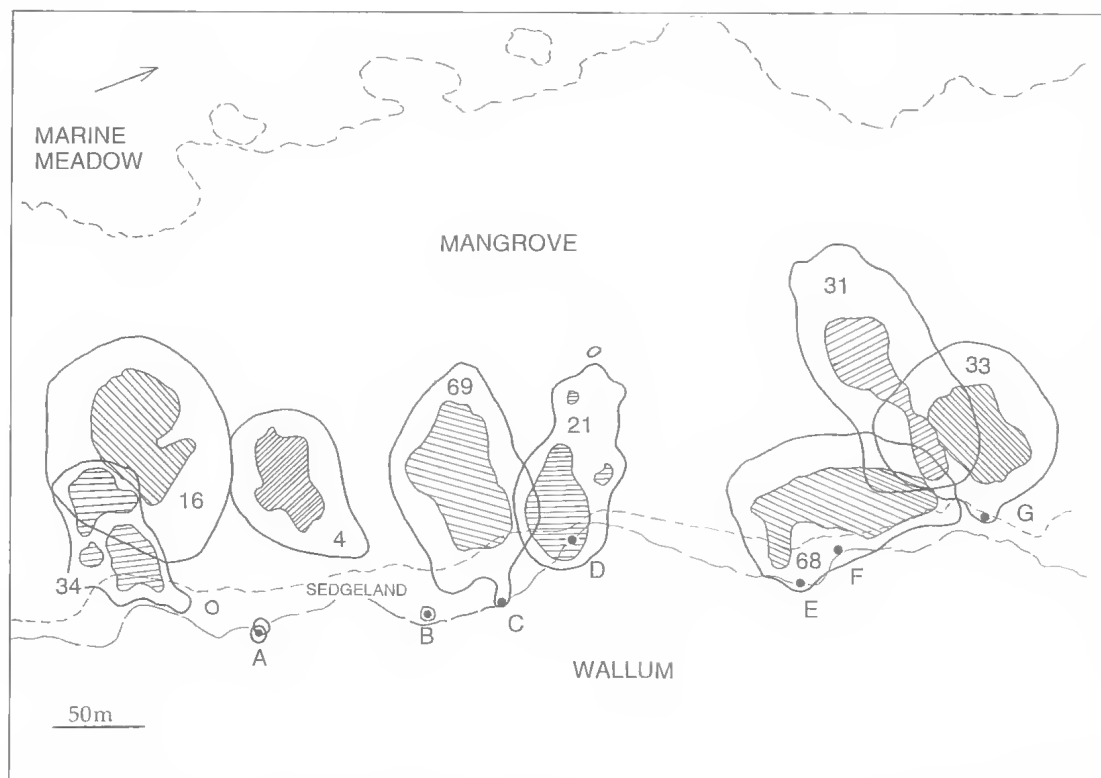


FIG. 19. Home range estimates of eight *Xeromys myoides* individuals from Rainbow Channel (Site 2). For home ranges, solid black lines show 95% isopleths of Harmonic Mean measures, hatched areas represent core areas (65% isopleths). Sub-adult male 34 is from nest A, as is adult male 16, adult female 4 is from nest B, adult female 69 from nest C, adult female 21 from nest D, adult male 68 from nest E, adult female 31 from nest F and adult male 33 from nest G. All nests except B are at the supralittoral ecotone between marine sedgeland and wallum woodland. The arrow points north.

HM 60-65% isopleths) for Rainbow Channel adults averaged around 0.20ha, with adult male core area being estimated at around 0.19ha and adult females at approx. 0.20ha. The Canalpin Creek male had a core area estimated at around 0.76ha. Core areas of the eight Rainbow Channel animals did not overlap, but animals moved in and out of their neighbouring territorial peripheries.

REPRODUCTION. Scrotal males were recorded in the population in all months except January, February and April (few traps were set during February, none in April, and one young adult male was trapped in January). Females, presumed to be pregnant by their swollen appearance and increased weights, were recorded in the months of January, May, August, September and October. Females with enlarged nipples were recorded from July through to December. Juveniles were

recorded in the months of May, July, August and November. Little is known of litter size and nothing of the rate of growth of young *X. myoides* on North Stradbroke Island. Endoscopic examination of a nesting chamber in nest site 2 on the night of 26 October 1993 revealed a litter of four dark-skinned but hairless young. On detection of the tip of the endoscope the adult removed each pup separately to another location in the nesting mound.

In the absence of more information it would appear that *X. myoides* is capable of breeding throughout the year.

PARASITES. Nematodes were retrieved from the faeces of one adult female *X. myoides* (AF2) and from the stomachs of three subadults (QM JM9478, JM9479, JM9728) and one adult male (QM JM9480). These were assigned to the genus *Tikusnema* Hasegawa, Shiraishi & Rumpus 1992

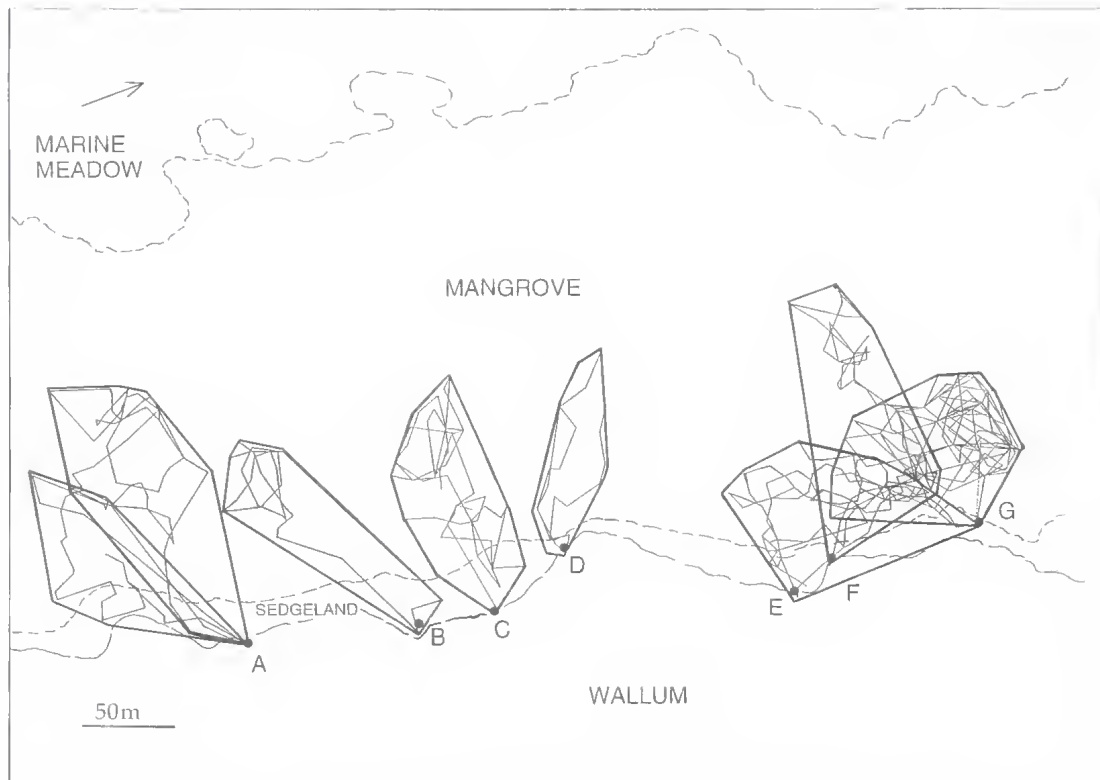


FIG. 20. Home range estimates (Minimum Convex Polygons) and actual trackways recorded for the eight *Xeromys myoides* individuals of Fig. 19, from Rainbow Channel (Site 2). The arrow points north.

as *T. vanduycki* Smales, 1995. The implications of the presence of acuariid nematodes, normally found in birds, in *X. myoides* and other small mammalian hosts is discussed by Smales (1995).

Mites, *Mesolaelaps australiensis* (Hirst, 1926), were retrieved from the body and ears of AF3, AF17, AM41 and AM15. This species has been recorded from a wide range of mammals, birds and reptiles in Australia and the South West Pacific (R. Domrow pers. comm.)

Ticks *Ixodes tasmani* were removed from the body of AM41 and from between the toes of the hind foot of AM7.

PREDATORS AND COMPETITORS. Carpet Pythons *Python spilotes* were recorded in sedgeland (Nov 1992) and inside mangrove forest (Nov 1992). A 2m specimen draped across *Rhizophora* prop roots approximately 10cm from the floor of the forest at low tide was probably hunting rats. Two Rough-scaled Snakes *Tropidechis carinatus* were recorded in the sedgelands at low tide (25 Feb. 1992, 10 Nov. 1992); one was investigating nest site 2 but was not observed entering any

burrows. Tawny Frogmouths *Podargus strigoides* commonly occurred in woodland adjacent to the mangrove zone but no owls were observed during the study. One frogmouth was observed at Canalpin Creek watching over mangrove flats. A three-syllable *Ninox*-like call was recorded in the Myora mangroves on 26 Oct. 1993 but the identity of the caller was not determined. Dissection of Cane Toads *Bufo marinus*, found feeding in the mangroves of Canalpin Ck revealed a diet consisting largely of crabs, marine pulmonates and amphipods. The crabs were of a similar size to those eaten by *X. myoides*.

It is possible that *Xeromys* may represent a potential prey item for *Hydromys*. Woollard et al. (1978) recorded young *Hydromys* in the diet of adults of that species (particularly males). If this behaviour occurs also in *Xeromys* it may provide one possible explanation (along with early expulsion or killing without ingestion) for the low record of sub-adult (dispersing) males captured during the survey (seven sub-adult males; 23 sub-adult females).

DISCUSSION

Xeromys myoides on North Stradbroke Island is a small, spotted, specialised, non-aquatic, non-arboreal, nocturnal murid rodent whose life history revolves around the island's western mangrove and adjacent sedgeland communities. The species appears to be carnivorous.

DIET. Truly carnivorous species of rodents which ingest more than 50%-80% animal food are very rare (Dieterlen & Statzner, 1981). African examples include the dendromurine rodents *Deomys furrugineus* and *Leimacomys buttneri* (Dieterlen, 1976); murine rodents of the genus *Lophuromys*, *Zelotomys* (Dieterlen, 1976) and *Colomys goslingi* (Dieterlen & Statzner, 1981). Neotropical examples include hesperomyine cricetids such as *Ichthyomys*, *Anatomys*, *Daptomys*, *Neustictomys*, *Rheomys* (Starrett & Fisler, 1970; Voss, 1988) and *Nectomys squamipes* (Ernest & Mares, 1986). Examples from Australia and New Guinea include the hydromyines *Hydromys* (Woollard et al., 1978; Menzies & Dennis, 1979), *Crossomys monktoni*, *Parahydromys asper* (Menzies & Dennis, 1979), *Leptomys elegans* (Dwyer, 1984), *Mayermys ellermani*, *Neohydromys fuscus*, *Pseudohydromys murina* and *P. occidentalis* (Jackson & Woolley, 1993) and probably also the genera *Paraleptomys* and *Microhydromys* (Menzies & Dennis, 1979; Flannery, 1990).

Carnivore digestive systems are noted for their simple stomachs, short small intestines, short large intestines and short or absent caeca (Hume, 1982). Barry (1977) commented that for most rodents, relative gut lengths are inaccurate indicators of relative absorptive surface area, given that a large proportion of the total absorptive surface of the hindgut may be found in the small intestine although this might account for a relatively small proportion of the total length. However, Barry also noted that for more carnivorous forms, relative lengths more accurately reflect relative absorptive surface areas because the caecum and colon are greatly reduced in relation to the small intestine. Gut morphology suggests that the diet of *Xeromys myoides* should not be totally carnivorous. Relative alimentary canal dimensions for five New Guinean hydromyines are presented by Jackson & Woolley (1993). The relative length of the small intestine of *Xeromys myoides* (85% of the total gut) is slightly shorter than that recorded for the four New Guinean hydromyines *Mayermys ellermani*, *Neohydromys fuscus*, *Pseudohydromys murinus*

and *P. occidentalis* (Jackson & Woolley, 1993), while the relative length of the large intestine (14%) is longer. However, relative caecum length in *X. myoides* (2%) is shorter than in *Mayermys ellermani*, *Neohydromys fuscus* and *Pseudohydromys occidentalis* and approaches the relatively short caecum length found in *P. murinus* (1%). Jackson & Woolley (1993) suggested that, on the basis of gut morphology and dietary analysis, *Pseudohydromys murinus* should not be considered an obligate carnivore. However, they noted that the plant material present in the guts of 22 of 24 sampled specimens could have been contained in the guts of their insect prey.

Relative lengths of the large intestine and caecum in *Xeromys myoides* closely approximate those of *Hydromys chrysogaster* (pers. obs.) which, although recorded eating a wide variety of vertebrate and invertebrate prey (Brazenor, 1936; Troughton, 1941; Barrett, 1955; McNally, 1960; Fleay, 1964; Woollard et al., 1978; Harris, 1978) has rarely been reported consuming vegetation. Brazenor (1936: 66) noted them to eat 'coarse grass or rushes' and Barrett (1955: 119) commented that they were 'partly vegetarian'. Woollard et al. (1978) concluded that plants were consumed as trace items but increased in importance in winter when resources were low. Harris (1978) recorded crustaceans as major prey items of *Hydromys chrysogaster* at three sites in south-eastern Queensland but did not observe animals feeding on vegetation, nor detect vegetation in scats. At two of these sites mammalian prey accounted for up to 9% of prey and 5% of the volume of scats.

Plant foods have, to date, not featured prominently in the diet of *Xeromys myoides*. The components of scats (from five individuals) and entire gut contents (three individuals) have reflected observed feeding preferences (recorded from 9 wild individuals) and included gross items such as mollusc viscera, shell and operculae, crustacean shell and gills, sand and hair (*X. myoides*). Microscopic examination of gut contents has revealed plant material in the form of xylum elements, parenchyma and fibre, probably from mangrove propagules ingested by (probably) crustacean prey (J. Bertram pers. comm.).

HOME RANGE. Individuals of *Xeromys* tracked throughout the year in this study at Rainbow Channel had home ranges (95% isopleths) which abutted or overlapped outlying areas of those of their neighbours (Figs 19, 20). However core

arcas (65% isopleths) did not overlap. Predictably, adult males had larger home ranges (average MCP 0.77ha) than females (0.53ha) and it was assumed that this reflected an investment of female defence and male repulsion that took the territorial limits beyond the male's dietary requirements. Females had smaller home ranges which, presumably, provided them with quick access to resources as close to their nests (and young) as possible. *Xeromys myoides* stands to gain much from the microhabitat specialisation of the mangrove crab population. At low tide the rats can exploit common species such as *Parasesarma erythrodactyla* out toward the seaward limit of the mangroves. During high tides, when access is blocked to the mangrove's most productive zones, those crabs which extend into the high intertidal or terrestrial zones (e.g., *Helice leachi*) can be exploited. Given that large body size does not increase an animal's capacity to acquire food, a small size of around 40g (as is the case of *X. myoides*) could be interpreted as the evolutionary optimum for harvesting the commonest of mangrove crabs without resorting to a semiaquatic life style such as that seen in the much larger *Hydromys chrysogaster* (Water Rat).

X. myoides appeared to respond more quickly to scent than any other stimulus offered by its prey, and it was suspected that given the daily flushing of home ranges, scent laid down inside erect hollow trunks of living trees might represent a cost effective method of home range familiarisation and territorial defence.

Schoener (1969) predicted that declines of prey abundance might be offset by expansions in either prey types or home ranges. In *Hydromys*, home range size has been shown to be smaller in areas of high substrate complexity, notably a high incidence throughout the home range of aquatic vegetation, stumps, sunken logs, eroded embankments and exposed roots (Harris, 1978). The same appears to be true for *Xeromys* on North Stradbroke Is. At Rainbow Channel the mangrove community is wide (200m from the marine meadow to the sedgeland) and diverse, with dense forests of *Rhizophora stylosa* and *Avicennia marina*. The substrate is complex with abundant trunk and root hollows, labyrinths of prop roots, flotsam rafts of twigs, propagules, leaves and eel-grass suspended on prop roots, a profusion of fallen logs and timber flotsam, and an abundance of tidal pools. Average home range size for adult males (N=3) from Rainbow Channel was 0.78ha (HM), 0.75ha (MCP). At Canalpin

Ck (Site 5), an area of *Avicennia* parkland, the mangrove zone was mostly narrow (maximum 20m), with widely spaced (average 5.2m) mature trees and very low substrate complexity. The home range of the only adult male (A89) tracked at Canalpin Ck was larger at 7.35ha (HM), 3.42ha (MCP). From its nest in the supralittoral bank, this male emerged to follow the line of the supralittoral bank for 300m to an area of greater microhabitat diversity and broader mangrove width where it foraged until returning to its nest at dawn (Fig. 21).

Structural diversity of the mangrove community and substrate microhabitat complexity probably determine centres of reproduction and dispersal on the island. In this respect, the communities of the Rainbow Channel and Stockyard represent the most important conservation zones for the species on, and close to, North Stradbroke.

Harris (1978) recorded lower weights in *Hydromys* from freshwater compared to estuarine habitats, and suggested that this reflected a difference in the quality of the two habitats. Although False Water-rats have been recorded in both habitat types throughout its east Australian range, no significant foraging took place inside the freshwater marshes and paperbark swamps immediately accessible to all radio-tagged individuals from Rainbow Channel or Canalpin Creek. Similarly, the outer (marine meadow) extremity of the mangrove zone, dominated by more widely separated, more mature *Avicennia*, was avoided. This study suggested that at these two localities, the most productive zone lay somewhere between *Xeromys* nests at the supralittoral bank and the first 100 metres into the mangroves.

AQUATIC ADAPTATION. There has been much speculation on the level of aquatic adaptation achieved in *Xeromys*. Thomas (1889) treated it as a terrestrial rat, Troughton (1954: 273) regarded it as 'an aquatic-feeding land rat', Redhead & McKean (1975: 352) contended that it was 'clearly ... aquatic', and Magnusson et al. (1976: 157) concluded that '*X. myoides* is basically a terrestrial rat that feeds on hard-shelled aquatic fauna'.

Results of this study indicate that *X. myoides* (on subtropical North Stradbroke Island at least) cannot be described as aquatic. Indeed, on a broad scale, the species scarcely qualifies as semiaquatic. Voss (1988), comparing a range of small (14-202g) semiaquatic-carnivorous lipotyphlans and Old World muroid rodents against closely

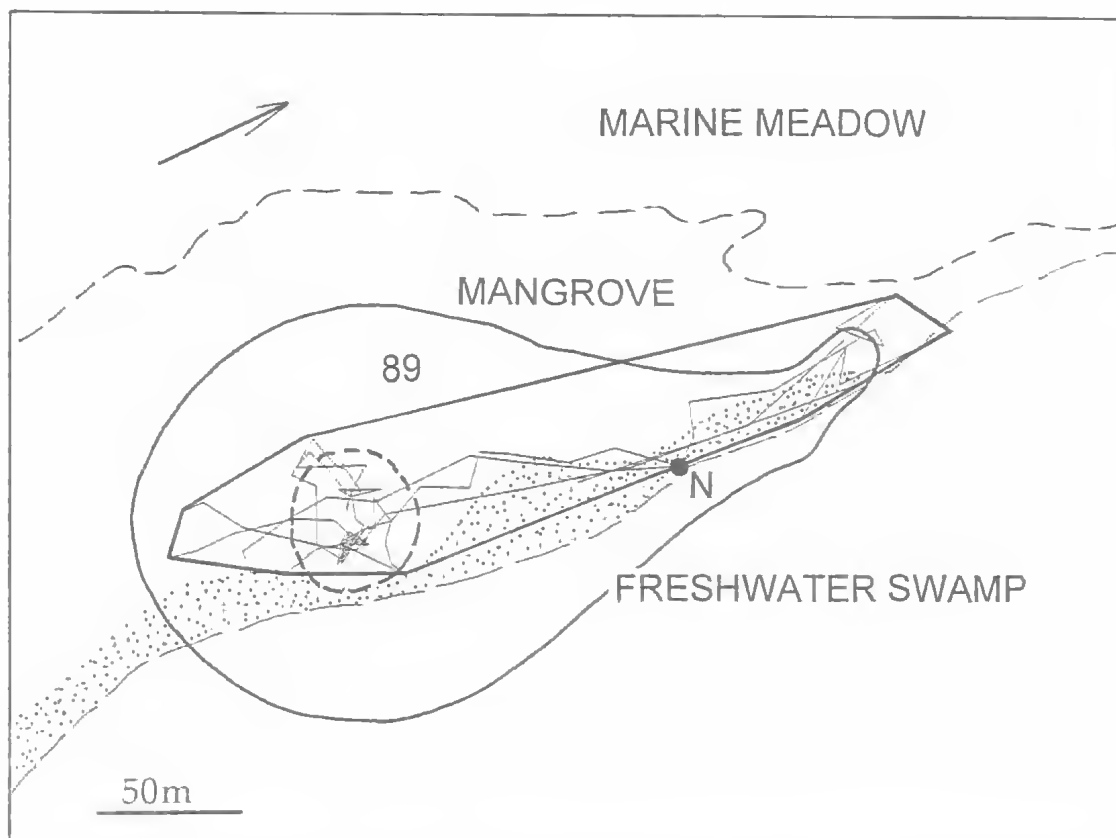


FIG. 21. Home range estimates (Harmonic Mean Measure – 95% isopleth [solid-line 'ellipse'] and 65% isopleth core area [broken-line 'circle'], Minimum Convex Polygon and actual trackway) recorded for adult male 89, Canalpin Creek (Site 5). Fine dotting denotes extensive area of shallow, brackish, stagnant lagoon. N denotes nest of AM89 in supralittoral bank. The arrow points north.

related terrestrial taxa, found semiaquatic species to converge morphologically in respect of the following suite of external and cranial attributes: 1, stiffer, more abundantly distributed mystacial vibrissae supported by thick mystacial pads; 2, reduced, incomplete or absent philtrum; 3, reduced and more densely furred pinnae; 4, hindfeet fringed with stiff, silvery hairs in plantar margins; 5, digits of hindfoot wholly or partly webbed; 6, round tails (in cross section) with longer, more dense ventral hairing; 7, metatarsal configuration approaching $IV > III > II \geq V > I$; 8, large infraorbital foramen; and 9, large foramen magnum.

In *Xeromys myoides* the mystacial vibrissae are no more abundant and only marginally stiffer than in terrestrial species, but the mystacial pads are conspicuously thick, imparting a breadth to the muzzle belied (in the extracted skull) by a rostrum of average width. The philtrum is absent,

but the pinnae are not greatly reduced (average length 12.5mm), being clearly visible above the head, nor are they thickly furred. The hindfeet have no fringing hairs and they lack webbing, the tail is thin and evenly furred dorsally and ventrally, and the metatarsal configuration ($III > IV > II > V > I$) is that of terrestrial muroids (terrestrial soricids and *Microgale*). The foramen magnum in *Xeromys* is not especially enlarged (there is considerable cranial reduction in the vicinity of the cerebellum), and the same applies to the infraorbital foramen. However, the molar row is reduced to two per quarter, the eyes are small, the posture couchant, the fur water-repellent, and the upper incisors, as in ichthyomyines, approach an orthodont condition.

The modest degree of aquatic specialisation exhibited by *X. myoides* is remarkably convergent on that of the 54–61g African Brook Rat *Colomys goslingi*, which consumes mainly tri-

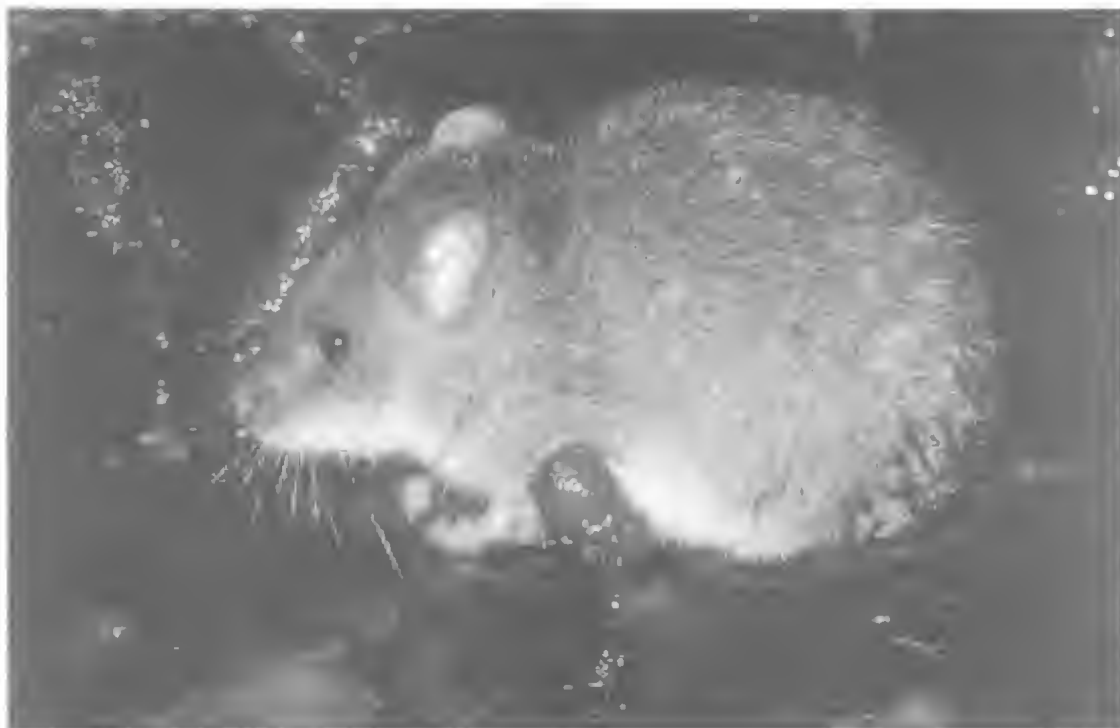


FIG. 22. Wild adult *Xeromys* shown in typical 'puddling' posture among pneumatophores. (Bruce Cowell).

chopteran larvae and terrestrial invertebrates in and adjacent to rainforest streams (Dieterlen, 1983). The reluctance of *Colomys* to enter deep water or to scale trees (Dieterlen, 1983) is also reminiscent of *Xeromys*. Other aspects of behaviour and ecology observed in the North Stradbroke study are consistent with the contention that *Xeromys* is an aquatic 'puddler' (Fig. 22) and not adapted to a truly semiaquatic lifestyle.

It is difficult to imagine what additional semiaquatic specialisation the littoral and supralittoral habitats might demand of *Xeromys*. Swimming adaptations, such as webbing of digits, fringing of lateral pes margins, elongation of lateral-most metatarsal proportions and development of a stiff ventral caudal brush, are clearly superfluous in a very small species to which deeper expanses of water must represent more of a risk of predation than an untapped resource (see Magnusson et al., 1976 for the record of *Xeromys* from a crocodile stomach). Similarly, stiffer, more abundantly distributed mystacial vibrissae are probably unnecessary given the species' observed preference for terrestrially acquired prey.

Observations of high daily food intake in captivity, rapid loss of body weight and ataxic behaviour associated with food deprivation, and

frenetic behaviour in the wild suggest a high metabolic level in the species. The very small size of *Xeromys* suggests that it might rapidly lose body heat through its relatively large surface area (compared to the volume of heat-producing tissue). This might be interpreted as particularly problematical for an animal continually in contact with water, especially as that small (vulnerable) body size may have already imposed a nocturnal life-style on the species.

However, the necessity to dissipate heat rather than the need to retain it may be the problem faced by *Xeromys*. Fanning & Dawson (1980) and Dawson & Fanning (1981) discuss the suggestion that many semiaquatic mammals have higher metabolic rates than those of similar-sized terrestrial mammals, their increased heat production compensating for losses to the aquatic environment. They conclude for the hypothermia-prone *H. chrysogaster* (Water Rat), that fur insulation (not tissue) is the major component of the rat's total insulation and that the ability of the fur to maintain an air layer between the skin and the water results in a significant retardation of the rate of heat loss.

There has been no published research to date on the insulative properties of the fur of *Xeromys*

although its water-repellent nature has been commented on by Watts & Aslin (1981) and Redhead & McKean (1975: 350) '... on leaving the water, *X. myoides* was dry, compared to *M. littoralis* which resembled the proverbial drowned rat'. The hair of *Xeromys* has been described as 'Pseudomys-like and unlike that of *H. chrysogaster*. It lacked 'shields' characteristics of other aquatic mammals and exhibited no structure known to impart water repellency' (B. Triggs pers. comm.). Despite its close association with an extremely wet, muddy habitat, and its tendency to sit, half-submerged, in small puddles for extended periods (Fig. 22), no examples of dirty, bedraggled or 'soggy' *Xeromys* were observed during the present study.

Dawson & Fanning's (1981) comments on the potential problems of heat loss faced by amphibious mammals when on land may have relevance to *Xeromys* if the water-repellent nature of its fur brings with it the associated cost of extra insulation. Given its avoidance of swimming, *Xeromys* may deal with the problem of heat dissipation by occupying saturated mud/peat/sand nesting mounds during the day and by 'puddling' while foraging at night (Fig. 22). In this respect it is difficult to deny an initial impression that the sparsely-haired tail and soft, near-naked, highly vascular pads of the hind feet of *X. myoides* represent surfaces evolved to dissipate heat. If this conjecture is correct, the southerly extent of distribution for this species might be determined not so much by thermoregulatory problems associated with decreasing ambient temperature and body heat loss, but by the decreasing abundance and diversity of suitable prey in less complex temperate mangrove forests (Clough, 1982; Hutchings & Saenger, 1987).

Xeromys myoides is a highly specialised terrestrial muroid rodent especially adapted to the littoral zone, one of the harshest of environments available to mammals. Its level of adaptation should not be regarded as an early stage of specialisation toward a more truly semiaquatic form, but a successful end product.

STATUS. *Xeromys myoides* has been described as 'one of the rarest of our native mammals' (Ride, 1970), 'vulnerable to changes caused by man' (Watts & Aslin, 1981), 'rare, scattered (probably at risk in some habitats and extinct in others)' (Redhead, 1983) and 'vulnerable' (Kennedy, 1990; Van Dyck, 1991). More recently it has been listed in the Rodent Action Plan with

nine other Australian rodents as 'rare or insufficiently known' (Lee, 1995).

This study has demonstrated that no special skill is required in capturing *X. myoides*, and it suggests that mangrove surveying elsewhere for *Xeromys* has probably been inadequate. However, the other possibility that North Stradbroke Island's fecund *X. myoides* population might represent the makings of an island remnant population such as that seen in *Leporillus conditor*, *Lagostrophus fasciatus*, *Setonix brachyurus* or *Bertongia lesueur*, should not be ignored. Given the proximity (200m) of areas such as Stockyard (southern North Stradbroke Island) to the complex mosaic of mangrove communities associated with lower Moreton Bay and the mainland, it seems likely that at the very least, the lower Moreton Bay islands should support populations of *X. myoides* similar to that of North Stradbroke. The number of mainland records also suggests that the rat is widespread and of reasonably broad habitat tolerance. However, until the North Stradbroke Island population is put into a broader mainland perspective the conservation status of *Xeromys myoides* will remain in question.

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